

Recent Results From CLEO on $D^0 - \overline{D^0}$ Mixing, CP Violation in D^0 Decays, and D^{*+} Width

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We present preliminary results of several analyses searching for the effects of CP violation and mixing in the decay of D^0 mesons. We find no evidence of CP asymmetry in five different two-body decay modes of the D^0 to pairs of light pseudo-scalar mesons: $A_{CP}(K^+K^-) = (+0.05 \pm 2.18 \pm 0.84)\%$, $A_{CP}(\pi^+\pi^-) = (+2.0 \pm 3.2 \pm 0.8)\%$, $A_{CP}(K_S^0\pi^0) = (+0.1 \pm 1.3)\%$, $A_{CP}(\pi^0\pi^0) = (+0.1 \pm 4.8)\%$, and $A_{CP}(K_S^0K_S^0) = (-23 \pm 19)\%$. We present the first measurement of the rate of wrong-sign $D^0 \rightarrow K^+\pi^-\pi^0$ decay: $R = 0.0043^{+0.0011}_{-0.0010} \pm 0.0007$. We also describe a measurement of the mixing parameter $y_{CP} = \frac{\Delta\Gamma}{2\Gamma}$ by searching for a lifetime difference between the CP neutral $K^-\pi^+$ final state and the CP even K^+K^- and $\pi^+\pi^-$ final states. Under the assumption that CP is conserved we find $y_{CP} = -0.011 \pm 0.025 \pm 0.014$. Finally, we present our measurement of the D^{*+} width: 96 ± 4 (stat) ± 22 (syst) keV.

1 Introduction and Motivation

The study of mixing in the K^0 and B_d^0 sectors has provided a wealth of information to guide the form and content of the Standard Model. In the framework of the Standard Model, mixing in the charm meson sector is predicted to be small¹, making this an excellent place to search for non-Standard Model effects. Similarly, measurable CP violation (CPV) phenomena in strange and beauty mesons are the impetus for many current and future experiments. The Standard Model predictions for CPV in charm meson decay are of the order of 0.1%², with one recent conjecture of nearly 1%³. Observation of CPV in charm meson decay exceeding the percent level would be strong evidence for non-Standard Model processes.

A D^0 can evolve into a $\overline{D^0}$ through “ordinary” on-shell intermediate states, or through off-shell intermediate states, such as those that might be present due to new physics. We denote the amplitude through the former (latter) states by $-iy$ (x), in units of $\Gamma_{D^0}/2$ ⁴. The Standard Model contributions to x are suppressed to $|x| \approx \tan^2\theta_C \approx 5\%$ and the Glashow-Iliopoulos-Maiani⁵ cancellation could further suppress $|x|$ down to $10^{-6} - 10^{-2}$. Many non-Standard Model processes could lead to $|x| > 1\%$. Contributions to x at this level could result from the presence of new particles with masses as high as $100 - 1000$ TeV⁶. Signatures of new physics include $|x| \gg |y|$ and CP violating interference between x and y or between x and a direct decay amplitude.

“Wrong sign” (WS) processes, such as $D^0 \rightarrow K^+\pi^-\pi^0$, can proceed directly through doubly-Cabibbo-suppressed decay (DCSD) or through mixing and subsequent Cabibbo-favored decay (CFD). Both DCSD and mixing followed by CFD can contribute to the time-integrated WS rate, $R = (r + \bar{r})/2$ and the inclusive CP asymmetry $A = (r - \bar{r})/(r + \bar{r})$, where $r =$

$\Gamma(D^0 \rightarrow f)/\Gamma(\overline{D^0} \rightarrow f)$, \bar{r} is the charge conjugated quantity, and f is a WS final state, such as $K^+\pi^-\pi^0$.

The different contributions to R and A can be separated by studying the proper decay time dependence of WS final states, as we have done in $D^0 \rightarrow K^+\pi^-$ ⁷, and has been done by FOCUS⁸. The differential WS rate relative to the time-integrated right sign (RS) process, in time units of the mean D^0 lifetime, $\tau_{D^0} = (415 \pm 4)\text{fs}$ ⁹, is given by $r(t) \equiv [R_D + \sqrt{R_D}y't + \frac{1}{4}(x'^2 + y'^2)t^2]e^{-t}$ ¹⁰. R_D is the relative rate of DCSD, $y' \equiv y \cos\delta - x \sin\delta$, $x' \equiv x \cos\delta + y \sin\delta$, and δ is the strong phase between the DCSD and CFD amplitudes. There are theoretical arguments that δ should be small¹¹, although this should not be taken for granted.

A measurement of $\Gamma(D^{*+})$ opens an important window to non-perturbative strong physics involving heavy quarks. The basic framework of the theory is well understood, however, there is still much speculation - predictions for the width range from 15 keV to 150 keV¹³. We know the D^{*+} width is dominated by strong decays since the measured electromagnetic transition rate is small, $(1.68 \pm 0.45)\%$ ¹⁴. A measurement of the width of the D^{*+} gives unique information about the strong coupling constant in heavy-light systems.

2 General Experimental Method

All of the analyses discussed herein, unless otherwise stated, use the same data set and reconstruction techniques described below. The data set was accumulated between February 1996 and February 1999 and corresponds to 9.0 fb^{-1} of e^+e^- collision data at $\sqrt{s} \approx 10.6$ GeV provided by the Cornell Electron Storage Ring (CESR). The data were recorded by the CLEO II detector¹² upgraded with the installation of a silicon vertex detector (SVX)¹⁵ and by changing the drift chamber gas

from an argon-ethane mixture to a helium-propane mixture. The upgraded configuration is referred to as CLEO II.V.

The Monte Carlo simulation of the CLEO II.V detector is based on GEANT¹⁶, and simulated events are processed in the same manner as the data.

The D^0 candidates are reconstructed through the decay sequence $D^{*+} \rightarrow D^0 \pi_s^+$ ¹⁷. The charge of the slow pion (π_s^+) tags the flavor of the D^0 candidate at production. The charged daughters of the D^0 are required to leave hits in the SVX and these tracks are constrained to come from a common vertex in three dimensions. The trajectory of the D^0 is projected back to its intersection with the CESR luminous region to obtain the D^0 production point. The π_s^+ is refit with the requirement that it come from the D^0 production point, and the confidence level of the χ^2 of this refit is used to reject background.

The energy release in the $D^{*+} \rightarrow D^0 \pi_s^+$ decay, $Q \equiv M^* - M - m_\pi$, obtained from the above technique is observed to have a narrow width, of order 190 keV depending on D^0 decay mode, which is a combination of the intrinsic width and detector resolution. M and M^* are the reconstructed masses of the D^0 and D^{*+} candidates respectively, and m_π is the charged pion mass. In the mixing analyses described below, the distribution of candidates in the Q - M plane are fit to determine both RS and WS yields.

We calculate t using only the vertical component of the D^0 candidate flight distance. This is effective because the vertical extent of the CESR luminous region has $\sigma_{\text{vertical}} = 7\mu\text{m}$. The resolution on the D^0 decay point (x_v, y_v, z_v) is typically $40\mu\text{m}$ in each dimension. We express t as $t = M/p_{\text{vertical}} \times (y_v - y_b)/(c\tau_{D^0})$, where p_{vertical} is the vertical component of the total momentum of the D^0 candidate. The error in t , σ_t , is typically 0.4 (in D^0 lifetimes), although when the D^0 direction is near the horizontal plane σ_t can be large.

3 CP Violation in D^0 Decay

CP Violation in charm meson decay is expected to be small in the Standard Model, which makes this a good place to look for non-Standard Model effects. Cabibbo-suppressed charm meson decays have all the necessary ingredients for CP violation – multiple paths to the same final state and a weak phase. However, in order to get sizable CP violation, the final state interactions need to contribute non-trivial phase shifts between the amplitudes. Large final state interactions may be the reason why the observed ratio of branching ratios⁹ ($D^0 \rightarrow K^+ K^-$)/($D^0 \rightarrow \pi^+ \pi^-$) is roughly twice the predicted value. Thus, D^0 decays may provide a good hunting ground for CP violation.

Previous searches for mixing-induced⁷ or direct^{18,9} CP violation in the neutral charm meson system have set limits of $\sim 30\%$ or a few percent, respectively. We present results of searches for direct CP violation in neutral charm meson decay to pairs of light pseudo-scalar mesons: $K^+ K^-$, $\pi^+ \pi^-$, $K_S^0 \pi^0$, $\pi^0 \pi^0$ and $K_S^0 K_S^0$.

3.1 Search for CP Violation in $D^0 \rightarrow K^+ K^-$ and $D^0 \rightarrow \pi^+ \pi^-$ Decay

The asymmetry result is obtained by fitting the energy release (Q) spectrum of $D^{*+} \rightarrow D^0 \pi_s^+$ events for the yields from D^0 and $\overline{D^0}$ decays. The background-subtracted Q spectrum is fitted with a signal shape obtained from $K^+ \pi^-$ data and a background shape determined from Monte Carlo. The D^0 mass spectra are also fitted as a check.

We measure the CP asymmetry,

$$A = \frac{\Gamma(D^0 \rightarrow f) - \Gamma(\overline{D^0} \rightarrow f)}{\Gamma(D^0 \rightarrow f) + \Gamma(\overline{D^0} \rightarrow f)},$$

where the flavor of the D^0 is tagged by the slow pion charge in $D^{*+} \rightarrow D^0 \pi_s^+$. The decay asymmetry may be measured using this method because the production and strong decay of $D^{*\pm}$ are CP -conserving.

The parameters of the slow pion dominate the Q distribution, so all modes have the same shape. We do the fits in bins of D^0 momentum to eliminate bias arising from differences in the D^0 momentum spectra between the data and the MC. The preliminary results are $A(K^+ K^-) = 0.0005 \pm 0.0218$ (stat) ± 0.0084 (syst) and $A(\pi^+ \pi^-) = 0.0195 \pm 0.0322$ (stat) ± 0.0084 (syst).

We use many variations of the fit shapes, both empirical and analytical, to assess the systematic uncertainties due to the fitting procedure (0.69%). We also consider biases due to the detector material (0.07%), the reconstruction software (0.48%), and forward–backward acceptance variations ($c\bar{c}$ pairs are not produced symmetrically in the forward/backward directions in $e^+ e^-$ collisions at $\sqrt{s} \sim 10.6$ GeV, and the collision point was not centered exactly in the middle of the detector) (0.014%).

The measured asymmetries are consistent with zero, and no CP violation is seen. These results are among the most precise measurements^{18,19}.

3.2 Search for CP Violation in $D^0 \rightarrow K_S^0 \pi^0$, $D^0 \rightarrow \pi^0 \pi^0$ and $D^0 \rightarrow K_S^0 K_S^0$ Decay

This analysis²⁰ differs from the other analyses presented in this paper in some of its reconstruction techniques and in the data set used. The $\pi^0 \pi^0$ and $K_S^0 \pi^0$ final states do not provide sufficiently precise directional information about their parent D^0 to use the intersection of the D^0

projection and the CESR luminous region to refit the slow pion, as described in Section 2. The $K_S^0 K_S^0$ final state is treated the same for consistency. This analysis uses the data from both the CLEO II and CLEO II.V configurations of the detector, corresponding to 13.7 fb^{-1} of integrated luminosity.

The K_S^0 and π^0 candidates are reconstructed using only good quality tracks and showers. The tracks (showers) whose combined invariant mass is close to the K_S^0 (π^0) mass are kinematically constrained to the K_S^0 (π^0) mass, improving the D^0 mass resolution. The tracks used to form K_S^0 candidates are required to satisfy criteria designed to reduce backgrounds from $D^0 \rightarrow \pi^+ \pi^- X$ decays and combinatorics. D^0 candidates with masses close to the known D^0 mass are selected to determine the asymmetry A . Prominent peaks due to $D^{*+} \rightarrow D^0 \pi_s^+$ decay are observed in the Q distributions of all three decay modes.

The yields of D^0 and \overline{D}^0 candidates for a given final state are determined by subtracting the background yield obtained by fitting the sideband regions to a non-relativistic threshold function, $B(Q) = aQ^{1/2} + bQ^{3/2} + cQ^{5/2}$. The background yield under the signal is obtained by interpolation from the sidebands.

After background subtraction, we obtain 9099 ± 153 $K_S^0 \pi^0$ candidates, 810 ± 89 $\pi^0 \pi^0$ candidates, and 65 ± 14 $K_S^0 K_S^0$ candidates.

We have searched for sources of false asymmetries introduced by the π_s^+ finding (0.19%), fitting (0.5%), and backgrounds (0.35% $K_S^0 \pi^0$, 0% $\pi^0 \pi^0$ and 12% $K_S^0 K_S^0$). We find no significant bias, but apply the measured corrections and add their uncertainties to the total. We obtain the results $A(K_S^0 \pi^0) = (+0.1 \pm 1.3)\%$, $A(\pi^0 \pi^0) = (+0.1 \pm 4.8)\%$ and $A(K_S^0 K_S^0) = (-23 \pm 19)\%$, where the uncertainties contain the combined statistical and systematic uncertainties. All systematic uncertainties, except for the 0.5% uncertainty due to possible bias in the fitting method, are determined from data and would be reduced in future higher luminosity samples.

All measured asymmetries are consistent with zero, and no indication of CP violation is observed. This measurement of $A(K_S^0 \pi^0)$ is a significant improvement over previous results, and the other two asymmetries reported are first measurements.

4 First Rate Measurement of Wrong-Sign $D^0 \rightarrow K^+ \pi^- \pi^0$ Decay

$D^0 \rightarrow K \pi \pi^0$ candidates are reconstructed using the selection criteria described in Section 2, with additional requirements specific to this analysis. In particular, π^0 candidates with momenta greater than 340 MeV/c are reconstructed from pairs of photons detected in the CsI

crystal calorimeter. Backgrounds are reduced by requiring specific ionization of the pion and kaon candidates to be consistent with their respective hypotheses.

We fit for the scale factor S which relates the small number of WS events, N_{WS} , to the large number N_{RS} of RS events: $N_{WS} = S \cdot N_{RS}$. If the U -spin symmetry prediction of $SU(3)$ -flavor is not badly violated²², we would expect the WS channel to have a different resonant substructure than that observed in the RS data. We account for the efficiency difference which could arise from this by allowing a correction factor C : $R = S \cdot C$.

The scale factor S is measured by performing a two-dimensional maximum likelihood fit to the distribution in Q and M . The signal distribution in these variables is taken from the RS data. The backgrounds are broken down into three categories: 1) RS $\overline{D}^0 \rightarrow K^+ \pi^- \pi^0$ decay combined with an uncorrelated π_s , 2) combinations from $e^+ e^- \rightarrow u\bar{u}, d\bar{d}$, and $s\bar{s}$, and 3) combinations from charm particle decays other than correctly reconstructed RS \overline{D}^0 decays. The background distributions are determined using a large Monte Carlo sample, which corresponds to approximately eight times the integrated luminosity of the data sample. The Q - M fit yields a WS signal of 38 ± 9 events and a ratio $S = 0.0043_{-10}^{+11}$. Projections of the data and fit results in slices through the signal region in each variable are shown in Fig. 1. The statistical significance of this signal is found to be 4.9 standard deviations.

The correction factor C is determined using a fit to the Dalitz plot of the WS data. The RS mode was recently fitted by CLEO²¹ and found to have a rich Dalitz structure consisting of $\rho(770)^+$, $K^*(892)^-$, $\overline{K}^*(892)^0$, $\rho(1700)^+$, $\overline{K}_0(1430)^0$, $K_0(1430)^-$, and $K^*(1680)^-$ resonances and non-resonant contributions. In this fit, the amplitudes and phases are initialized to the RS values, with those corresponding to the $K^*(892)^+$ and $K^*(892)^0$ resonances allowed to vary relative to the dominant $\rho(770)^-$ and other minor contributions. We measure a correction of $C = 1.00 \pm 0.02$ (stat). Studies are under way to examine the extent and significance of the surprising similarity between the RS and WS Dalitz plots.

We estimate an uncertainty of 14% on S due to the Monte Carlo Q - M background, based on a series of fits using specific background subregions of the Q - M plane. The 9.5% uncertainty in C has contributions from the unknown amplitudes and phases that are fixed in the determination of C (8%), the Dalitz plot fit method (3.6%), and the Dalitz plot of non- \overline{D}^0 backgrounds (3%). Other minor contributions come from mismodeling of selection variables (3%), and statistics of the Monte Carlo background sample (2.4%).

We measure the WS rate to be $R = 0.0043_{-0.0010}^{+0.0011}$ (stat) ± 0.0007 (syst) (preliminary). Work is in progress to use the lifetime distribution of this sample to yield independent limits on x' , y' , and

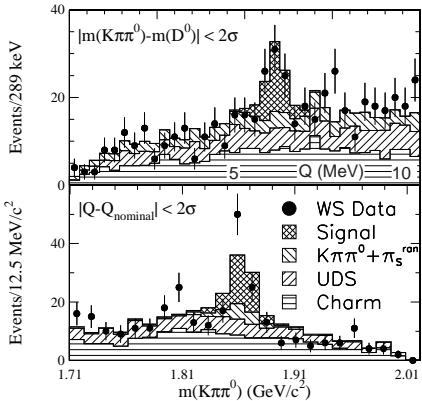


Figure 1: Results of the fit to the data to determine S . Projections in the variables Q (top) and M (bottom), after selecting the signal region (within two standard deviations) in the other variable.

R_{DCSD} .

5 Search for CP -Dependent Lifetime Differences Due to $D^0 - \bar{D}^0$ Mixing

In the limit of no CP violation in the neutral D system, we can express y as

$$y = \frac{\tau_{CP}}{\tau_{CP+}} - 1, \quad (1)$$

where τ_{CP} is the lifetime of a CP neutral state, such as $K^-\pi^+$, and τ_{CP+} is the lifetime of a CP even state, such as K^+K^- or $\pi^+\pi^-$. Thus, to measure y we simply measure the ratio of the lifetimes of $D^0 \rightarrow K^-\pi^+$ and $D^0 \rightarrow K^+K^-$ or $\pi^+\pi^-$. Since the final states are very similar, our backgrounds are small, and cross-feed among the final states is negligible, many of the sources of uncertainty cancel in the ratio. A similar analysis has recently been published by FOCUS comparing the $K^-\pi^+$ and K^+K^- final states²⁴.

We fit the proper time distributions of candidates near the D mass using an unbinned maximum likelihood fit. The proper time measurement technique is described in Section 2.

The signal likelihood function is an exponential convolved with three resolution Gaussians. The width of the primary Gaussian is due to the propagation of errors from the track fit to the flight distance and momentum for each candidate. The second and third Gaussians represent candidates that have been mismeasured by the addition of spurious tracking hits or due to hard non-Gaussian scatters in the material of the detector. The first of these has its width determined in the fit to the copious $K^-\pi^+$ sample, while the second is fixed to a

large value of 8 ps. The relative contribution of the two mismeasured signal resolutions is determined using the $K^-\pi^+$ data sample and fixed for the K^+K^- and $\pi^+\pi^-$ samples. According to our simulation, the fraction of the second Gaussian is about 4% of the well-measured signal and the third Gaussian is less than 0.1% of the signal. The probability for a candidate to be signal is determined by its measured mass M , and is based on a fit to that distribution.

The background is considered to have contributions with both zero and non-zero lifetimes. All parameters that describe the background are allowed to vary in the fits except for the width of the widest Gaussian which is fixed to 8 ps.

The background in all three samples has a large component with a lifetime consistent with that of the D^0 . This agrees with the prediction of our simulation that the background with lifetime is dominated by misreconstructed fragments of charm decays.

We calculate y separately for the K^+K^- and $\pi^+\pi^-$ samples. Systematic uncertainties are dominated by the statistical uncertainty in a Monte Carlo study used to determine small corrections, consistent with zero, that are applied to the measured result to account for differences between measured and generated values of the lifetimes (± 0.009). Additional significant systematic uncertainties come from variations in the description of the background (± 0.008), uncertainties in our model of the proper time resolution (± 0.005), and details of the fit procedure (± 0.005), where the listed values are the contribution to the average result. Our preliminary results are $y_{KK} = -0.019 \pm 0.029$ (stat) ± 0.016 (syst) and $y_{\pi\pi} = 0.005 \pm 0.043$ (stat) ± 0.018 (syst). We form a weighted average of the two to get $y = -0.011 \pm 0.025$ (stat) ± 0.014 (syst) (preliminary), which is consistent with zero. It is also consistent with our previous result using $D^0 \rightarrow K^+\pi^-$ and the FOCUS results using $D^0 \rightarrow K^+\pi^-$ and $D^0 \rightarrow K^+K^-$ ²⁴.

6 D^{*+} Width Measurement

The challenge of measuring the width of the D^{*+} is understanding the experimental resolution, which exceeds the width we are trying to measure. Unfortunately, there is no decay mode with small width, large cross-section, and similar kinematics to use as a calibration of the method. We depend on exhaustive comparisons between our detector simulation and data in order to understand the effect of candidates with mismeasured hits, errors in pattern recognition, or large angle Coulomb scattering on the measured width.

In addition to the cuts described in Section 2, we require events to be within the kinematically allowed regions of D^{*+} momentum, π_s^+ momentum, and $D^0-\pi_s^+$

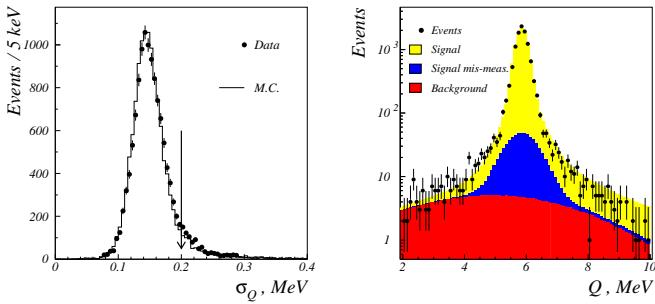


Figure 2: Distribution of σ_Q , the uncertainty on Q as determined from propagating track fitting errors (left). Fit to the data sample (right).

opening angle in order to remove a small amount of misreconstructed background. We also remove poorly measured events by requiring $\sigma_Q < 200$ keV and do not consider D^0 candidates within 0.3 radians of the horizontal plane.

We assume that the intrinsic width of the D^0 is negligible, $\Gamma(D^0) \ll \Gamma(D^{*+})$, implying that the width of Q is simply a convolution of the shape given by the D^{*+} width and the tracking system response function. We consider pairs of Q and σ_Q for the decay $D^{*+} \rightarrow \pi_s^+ D^0 \rightarrow K^- \pi^+ \pi_s^+$, where σ_Q is given for each candidate by propagating the tracking errors from the kinematic fit of the charged tracks.

The width is extracted using an unbinned maximum likelihood fit to the Q distribution. The observed Q distribution is fitted to a Breit-Wigner signal and polynomial background, with its shape fixed by the simulation.

For each candidate, the signal shape is convolved with a Gaussian resolution function with width given by the event-by-event error on Q , σ_Q . The detector resolution on Q is approximately 150 keV. We find excellent agreement between the simulation of σ_Q and that observed in the data, as shown in Fig. 2. This reflects the correct modeling of the kinematics and sources of errors on the tracks in the simulation, such as number of hits on a track and the effects of multiple scattering in detector material.

In order to account for poorly measured events, we allow a small fraction f_{mis} of the signal to be parameterized by a single Gaussian resolution function of width σ_{mis} . In the fit, we constrain the level of this contribution to $f_{mis} = 5.3 \pm 0.5\%$. This value was determined by fitting a range of simulated D^{*+} widths, while allowing σ_{mis} to vary.

The fitter has been tested extensively using Monte Carlo samples generated with different $\Gamma(D^{*+})$ and is found to reproduce inputs ranging from 0 to 130 keV. In this study, we observe a bias of -2.7 ± 2.1 keV, which is

consistent with zero. We apply this small correction to our fit result.

We observe a corrected width of $\Gamma(D^{*+}) = 96.2 \pm 4.0$ (stat) keV.

We test the simulation of the Q distribution and estimate the corresponding systematic uncertainty by comparing its dependence on kinematic variables of the D^{*+} decay with data. Specifically, we compare the Gaussian peak width and mean as a function of P_{D^0} , $P_{\pi_s^+}$, $\theta_{D^0-\pi_s^+}$, $\partial Q/\partial P_{D^0}$, $\partial Q/\partial P_{\pi_s^+}$, and $\partial Q/\partial \theta_{D^0-\pi_s^+}$. The derivatives test correlations among the basic kinematic variables. We compare by dividing the sample into ten slices in each variable and fitting the ten distributions of Q to Gaussians.

We observe some discrepancy between the Gaussian mean of the Q peak in data and Monte Carlo as a function of $P_{\pi_s^+}$, $\partial Q/\partial P_{\pi_s^+}$, and $\partial Q/\partial P_{D^0}$. While measuring the mean Q is not our goal, we include the observed deviation as a systematic uncertainty of 16 keV on $\Gamma(D^{*+})$.

We find excellent agreement between the Gaussian width of the Q peak in data and Monte Carlo as a function of all variables if events are generated with an intrinsic width in the range $\Gamma(D^{*+}) = 90-100$ keV. Even when comparing with a sample of zero intrinsic width, we see excellent agreement in the dependence on the kinematic variables.

In order to test our modeling of effects that contribute to the tracking errors, we perform fits in which we allow a scale factor k to multiply the event-by-event error σ_Q . We estimate this effect by varying our cut on σ_Q from the nominal 200 keV in the range 75 keV to 400 keV. Several effects, such as improper modeling of material in the detector, could lead to deviations of k from unity. Repeating our analysis with all parameters fixed except k , we find $k = 1.00 \pm 0.04$. We measure an uncertainty of ± 11 keV on $\Gamma(D^{*+})$ by rerunning the analysis with k fixed at its limits.

We take into account correlations among the less well-measured parameters of the fit, such as k , f_{mis} , and σ_{mis} , by varying each parameter one standard deviation from its central fit value. We find an uncertainty of ± 8 keV.

Biases in the reconstruction are estimated by replacing reconstructed parameters with their generated values in the analysis. We find only a small bias in the reconstruction of the D^0 origin point. This contributes an uncertainty ± 4 keV.

Uncertainties from the background shape are determined by allowing the coefficients of the background polynomial to vary in the fit. We observe a change on the width of ± 4 keV.

These studies were confirmed using subsamples of the data. One sample uses events restricted to kinematic regions in which the mean Q and σ_Q are well-

modeled: $|\partial Q/\partial P_{D^0}| \leq 0.005$ and $|\partial Q/\partial P_{\pi^+}| \leq 0.05$. The other uses events in which very tight selection criteria are applied to the tracks. In both cases the background from poorly measured tracks is negligible and not included in the fit. We measure $\Gamma(D^{*+})$ to be consistent with our nominal sample: $(103.8 \pm 5.9 \text{ (stat)}) \text{ keV}$ ($(104 \pm 20 \text{ (stat)}) \text{ keV}$) in the former (latter) sample.

We measure the width of the D^{*+} to be $\Gamma(D^{*+}) = (96 \pm 4 \text{ (stat)} \pm 22 \text{ (syst)}) \text{ keV}$ (preliminary) by studying the distribution of the energy release in $D^{*+} \rightarrow D^0\pi^+$ followed by $D^0 \rightarrow K^-\pi^+$ decay.

This is the first measurement of the D^{*+} width, corresponding to a strong coupling¹³ of $g = 17.9 \pm 0.3 \text{ (stat)} \pm 1.9 \text{ (syst)}$ (preliminary). This is consistent with theoretical predictions based on HQET and relativistic quark models, but higher than predictions based on QCD sum rules.

7 Summary

We present preliminary results of several analyses searching for the effects of CP violation and mixing in the decay of D^0 mesons. We find no evidence of CP asymmetry in five different two-body decay modes of the D^0 to pairs of light pseudo-scalar mesons: $A_{CP}(K^+K^-) = (0.05 \pm 2.18 \pm 0.84)\%$, $A_{CP}(\pi^+\pi^-) = (2.0 \pm 3.2 \pm 0.8)\%$, $A_{CP}(K_S^0\pi^0) = (+0.1 \pm 1.3)\%$, $A_{CP}(\pi^0\pi^0) = (+0.1 \pm 4.8)\%$ and $A_{CP}(K_S^0K_S^0) = (-23 \pm 19)\%$. We present the first measurement of the rate of WS $D^0 \rightarrow K^+\pi^-\pi^0$ decay: $R = 0.0043^{+0.0011}_{-0.0010} \pm 0.0007$. We describe a measurement of the mixing parameter $y = \frac{\Delta\Gamma}{2\Gamma}$ by searching for a lifetime difference between the CP neutral $K^+\pi^-$ and the CP even K^+K^- and $\pi^+\pi^-$ final states. Under the assumption that CP is conserved we find $y = -0.011 \pm 0.025 \pm 0.014$. Finally, we describe our preliminary measurement of the D^{*+} intrinsic width of $\Gamma(D^{*+}) = (96 \pm 4 \text{ (stat)} \pm 22 \text{ (syst)}) \text{ keV}$.

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